Eco-life in a Smart Apartment Room with an Integrated Smart Tap Network

September, 2010

- "*i*-Energy" R&D Demonstration (Stage I) -

Professor Takashi MATSUTAMA of the Graduate School of Informatics, Kyoto University has proposed the concept of "***i*-Energy**" (see for details http://www.i-energy.jp/data/i-Energy_revised.pdf) and promoted related research and development for these several years. He also engaged in a wide range of joint activities on an international basis to establish in May 2009 an "*i*-Energy WG (Working Group)" (see http://www.i-energy.jp/en_index.html) as a collaborative organization of industries, local and national governments, and academia.

With recognition of these research and development activities, Kansai (Keihanna) Science City was selected as one of four "Next-Generation Energy and Social Systems Demonstration Areas" by the Ministry of Economy, Trade and Industry through the joint proposal of *i*-Energy WG and Kyoto Prefecture in April 2010, and its demonstration experiments in living environments are about to commence.

As the first step to demonstrate the practical effectiveness and utilities of the *i*-Energy concept, members of *i*-Energy WG, the Matsuyama Lab. at Koto University, Enegate Co., Ltd., OMRON Corporation, Sumitomo Electric Industries, Ltd., Daiwa House Industry Co., Ltd., ROHM Co., Ltd., and the R&D Project on "Integration Technology for Information, Communications and Energy" sponsored by NICT (http://www.nict.go.jp/index.html) have developed an integrated Smart Tap network in an apartment room in Shijo Karasuma, Kyoto. In August 2010, the initial stage system has been completed and an open demonstration was conducted on 24th September 2010. The major functions of the system are:

(1) Real-time measurement and display of energy consumption characteristics of home appliances with Smart Taps

(2) Home server system which integrates various types of Smart Taps developed by different manufacturers

(3) Interactive visualization and control of energy consumption by home appliances

(4) Automatic recognition of home appliances by Smart Taps

(5) Security monitoring and malfunction detection of home appliances

In addition, this experiment is recognized as the R&D frontier project of "KEIHANNA Eco-City Next-Generation Energy and Social Systems Demonstration Project" authorized by the Ministry of Economy, Trade and Industry.

Functions of the Stage I System

As the initial stage of achieving *i*-Energy, Professor Takashi MATSUYAMA's research group and *i*-Energy WG are promoting development of the system for real-time measurement and display of detailed energy consumption patterns, security and safety monitoring of human and electrical appliances, consulting on energy saving, and highly-controlled energy saving, by attaching Smart Taps, with the functions of high-precision power measurement, signal processing and communication, to all electrical appliances inside houses and offices (Figure 1).

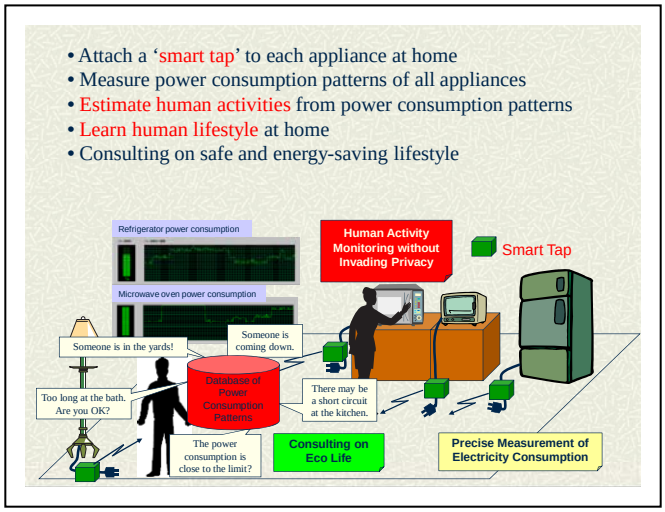


Figure 1 Integrated Smart Tap Network

Figure 2 Smart apartment room

Smart Taps developed respectively by the Matsuyama Lab. at Koto University, Enegate Co., Ltd., OMRON Corporation, Sumitomo Electric Industries, Ltd., ROHM Co., Ltd., and the R&D Project on "Integration Technology for Information, Communications and Energy," are installed on all the home appliances (50 devices) in a 1LDK (33m^2) apartment room, and data produced in real-life situations have been collected and analyzed since this June (Figure 2).

In the stage I system, the following functions have been developed: real-time measurement of energy consumption of home appliances, and an interactive monitoring and control system for energy saving, automatic recognition of appliances, and malfunction detection of appliances.

(1) Real-time measurement and display of energy consumption characteristics of home appliances with Smart Taps

The Smart Tap developed by Kyoto University (Figure 3) consists of current and voltage sensors, a microprocessor, a wireless (ZigBee) communication unit, and a power control unit, which can measure precisely current and voltage waveforms at 20 KHz high-speed data sampling rate. The following (2) - (5) functions are realized by softwares of Smart Taps.

By installing Smart Taps in electrical appliances inside homes and offices, the power consumption by each appliance can be monitored in real time, and energy saving is promoted by reduction of standby electricity and ensuring that devices are turned off when not in use.

A distinguishing feature of the Smart Tap developed by Kyoto University is that it has a continuous power control unit. Currently, automatic energy management functions using this feature are being developed and will be demonstrated in near future.

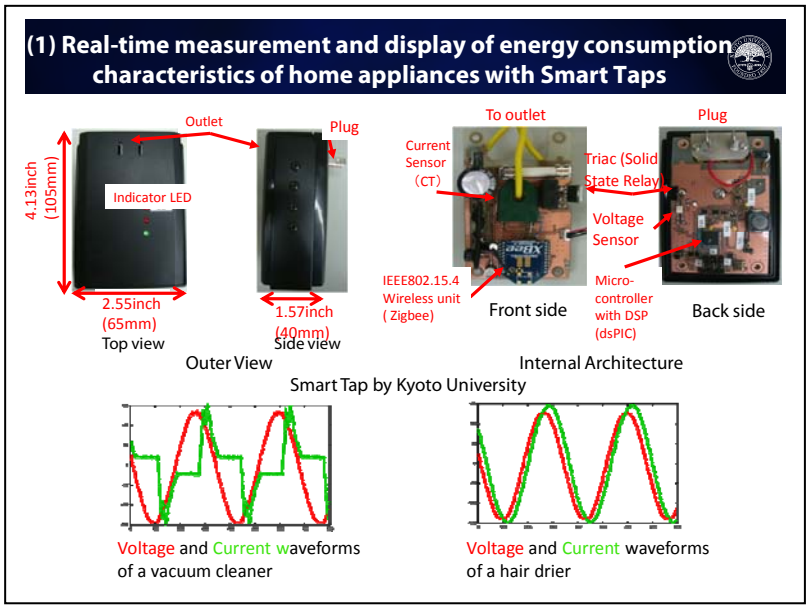


Figure 3 Outer view and internal architecture of the smart tap developed by Kyoto University and measured voltage and current waveforms of appliances.

(2) Home server system which integrates various types of Smart Taps developed by different manufacturers

Japanese and foreign research institutions and manufacturers developed Smart Taps with different functionalities. From the viewpoint of users, there is a strong need for a unified platform to integrate Smart Taps produced by different manufacturers, without caring about incompatibility problems.

i-Energy WG has developed a home server system using software called OSGi that enables integrated use of Smart Taps developed individually by the Matsuyama Lab. at Koto University, Enegate Co., Ltd., OMRON Corporation, Sumitomo Electric Industries, Ltd., ROHM Co., Ltd., and the R&D Project on “Integration Technology for Information, Communications and Energy” . The following functions (3) - (5), developed as application software for this home server, are designed to work with any models of Smart Taps.

Please note that all application softwares work with highly-functional Smart Taps as developed by Kyoto University, while some functions of the software do not work with Smart Taps that have fewer functions in order to reduce costs.

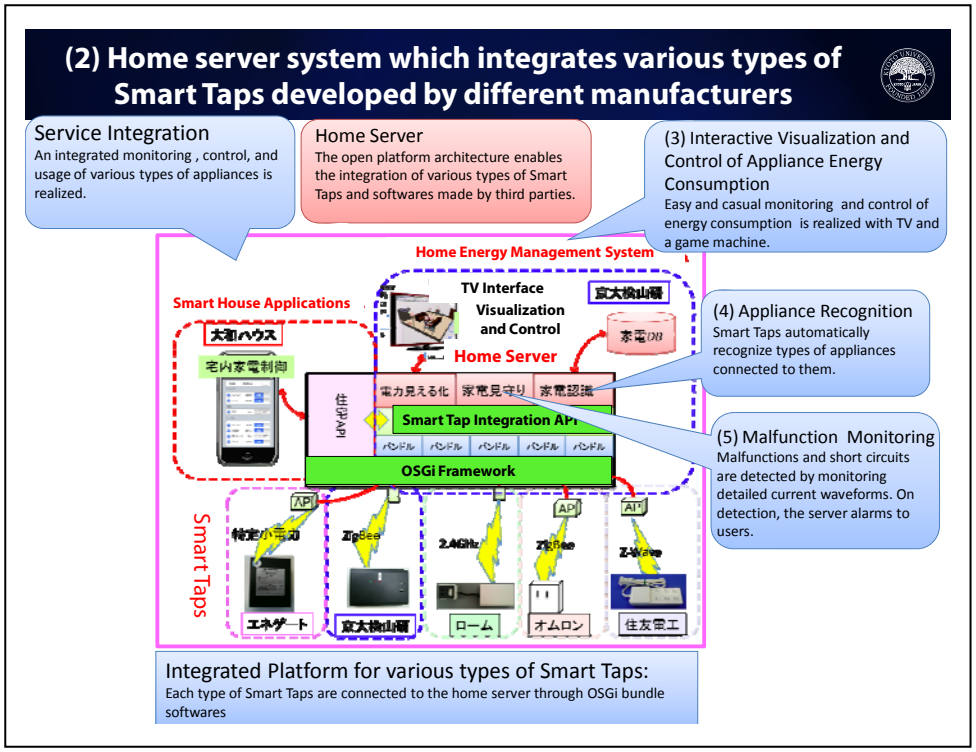


Figure 4 Architecture of the home server system

(3) Interactive visualization and control of energy consumption by home appliances

A real time interactive visualization and control system of energy consumption is developed as an application on the home server system. Characteristics of this application are

1. TV monitor and a game machine are used for the interactive visualization and control, which allows users to casually monitor energy consumption in everyday living environments, i.e. while they watch TV programs (Figure 5).
2. The energy consumption of each appliance is displayed in real time on the 3D map of the apartment room, which allows users to check the current and accumulated energy consumption values of each appliance in Wh and yen.
3. ON/OFF control of each appliance can be done with the game machine, which helps users to reduce wasted energy in everyday life.

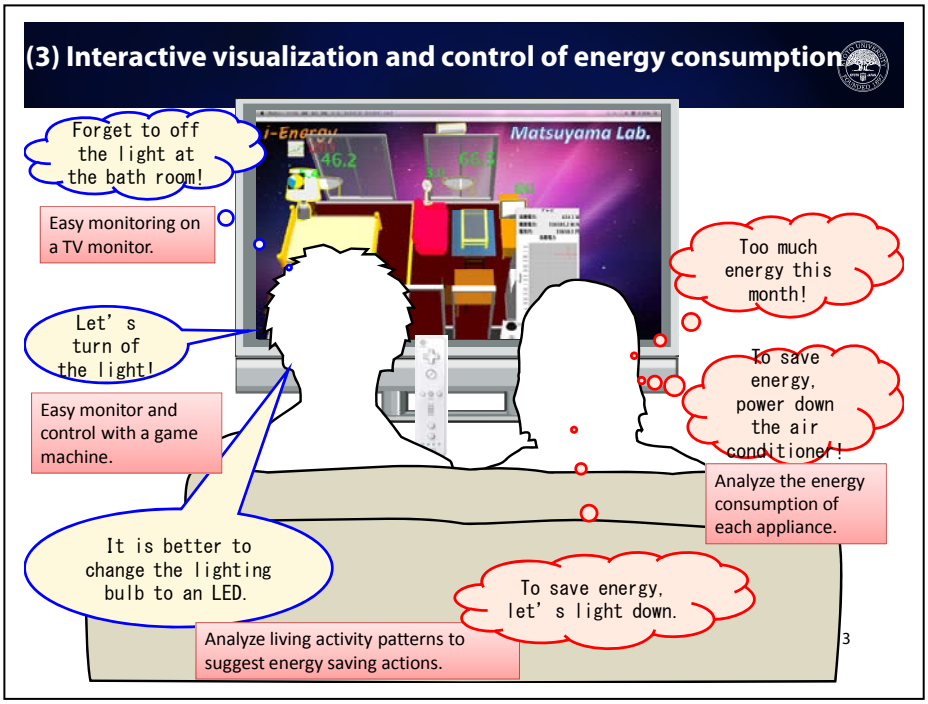
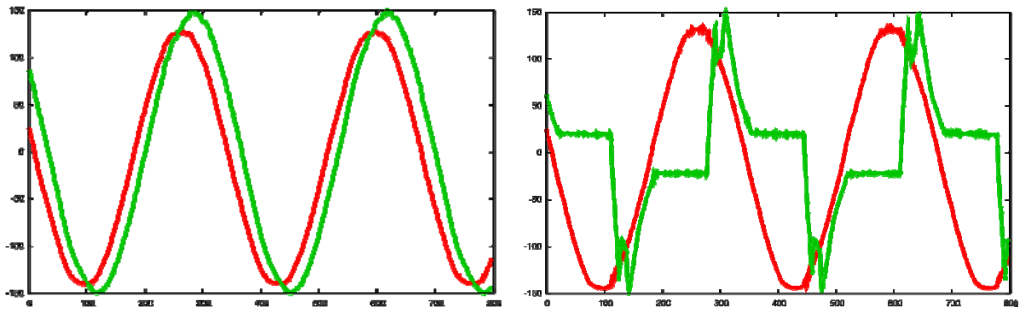


Figure 5 Casual monitoring of energy consumption with TV and a game machine

(4) Automatic recognition of home appliance by Smart Taps

Current waveforms measured by Smart Taps reflect characteristics of connected electrical appliances as shown in the graphs below.



Voltage and current waveforms of a hair drier (left) and a vacuum cleaner (right)

The location of use and type of home appliance can be identified when it is simply plugged in since the types of home appliances are recognized by analyzing precise current waveforms measured by Smart Taps. At the smart apartment room, the demonstration of automatic recognition of home appliances will be given by using a vacuum cleaner plugged in sockets of various rooms while cleaning the room.

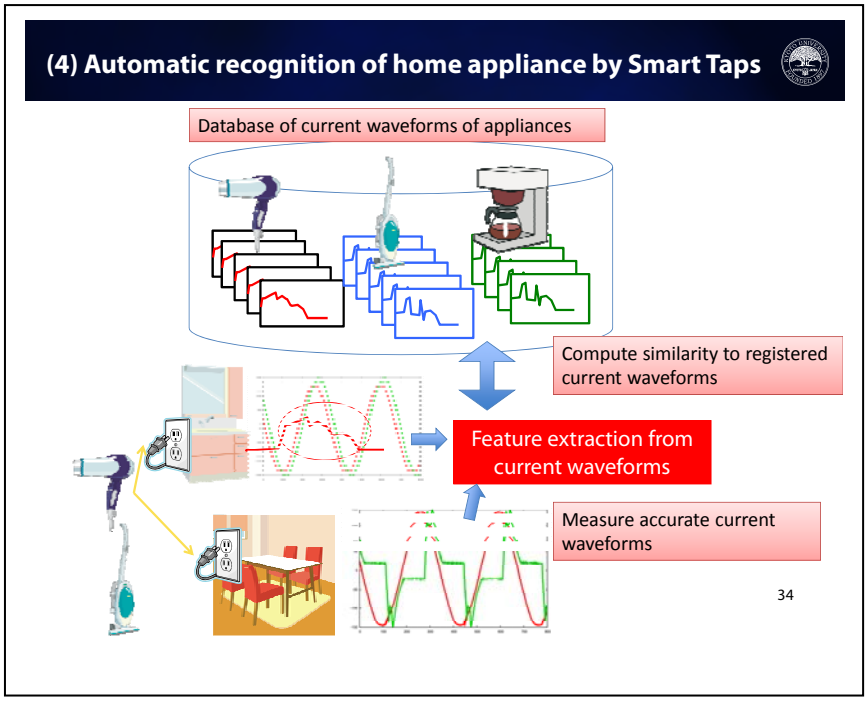


Figure 6 Automatic appliance recognition

(5) Security monitoring and malfunction detection of home appliances

As previously mentioned, precise current waveforms as shown in the above graphs can be measured by using Smart Taps. As current waveforms change when there are malfunctions in home appliances, electrical wiring, or electrical outlets, Smart Taps recognize such abnormal events to prevent fire and other accidents.

In the demonstration at the smart apartment room, the abnormality detection of an electrical fan is shown: the fan is stopped by inserting a hand.

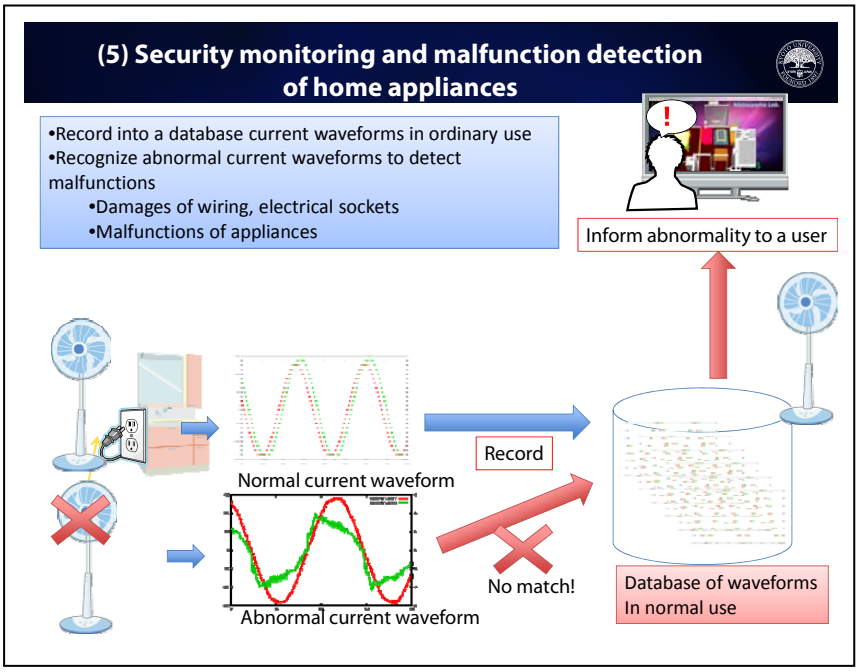


Figure 7 Abnormality detection by Smart Tap